

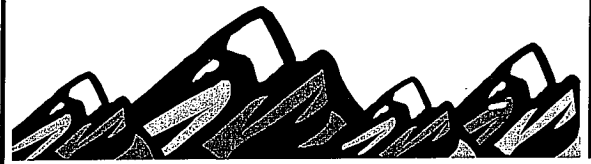
**2008 Conference on  
Precision Electromagnetic  
Measurements**

**Digest**

**8-13 June 2008**

**Broomfield, Colorado**

**CPEM 2008**



**NIST Boulder**

# CORRECTING FOR NONIDEAL PROBE LOCATIONS IN NEAR-FIELD SCANNING MEASUREMENTS OF ANTENNA PARAMETERS

R. C. Wittmann, M. H. Francis, and B. K. Alpert  
National Institute of Standards and Technology  
325 Broadway, Boulder, CO

## Abstract

We discuss efficient near-field to far-field transformation algorithms that relax the usual restriction that data points be located on regular grids on special surfaces (planar, spherical, or cylindrical).

## Introduction

It is not always practical or desirable to make uniformly spaced measurements; for example, the maintenance of positioning tolerances becomes more difficult as frequency is increased. Our method can (1) extend the frequency ranges of existing scanners, (2) make practical the use of portable scanners for on-site measurements, and (3) support schemes, such as plane-polar scanning, where data are intentionally collected on alternative grids.

Although "ideal" locations are not required, the actual probe positions must be known. We use a laser tracking device for this purpose. Typical laser tracker uncertainties do not exceed positioning tolerance requirements of  $\lambda/50$  to  $\lambda/100$  for microwave frequencies up to several hundred gigahertz. The laser tracker determines the location of a retroreflector located near the probe (Figure 1). Position and RF measurements are triggered simultaneously.

## Theory

Theory establishes a linear relationship

$$w = Q\xi \quad (1)$$

between the measurement vector  $w$  and the vector of unknown coefficients  $\xi$  that describe the radiation pattern of the antenna. The matrix  $Q$  is a known function of probe position. The number  $N^2$  of coefficients can be estimated with

$$N = Kka, \quad (2)$$

where  $K$  is a constant of order unity,  $k = 2\pi/\lambda$ , and  $a$  is the radius of the smallest sphere that contains the test antenna. Generally, the number of measurements

exceeds the number of unknowns and (1) is solved in the least-square sense.

When probe positioning is ideal, the planar and cylindrical scanning algorithms can find  $\xi$  in  $O(N^2 \ln N)$  operations. The computational complexity of the spherical scanning algorithm is  $O(N^3)$ . In contrast, straightforward Gaussian elimination is  $O(N^6)$ . For typical problem sizes ( $10^4 < N < 10^6$ ), the importance of computational efficiency is readily apparent.

In our approach to position correction, we use an iterative procedure (conjugate gradient) to find  $\xi$ . The complexity of each iteration is of the same order as the ideal positioning case. The number of iterations depends on desired computational accuracy and on conditioning (but not on  $N$ ).

Detailed accounts of probe-position correction algorithms for planar and spherical scanning may be found in [1] and [2]. NIST software is available for these cases.

## Example

Consider a radiometer antenna with an aperture diameter of 25 cm and an operating frequency of 31.65 GHz. The planar near-field data consist of 161 points in  $x$  by 161 points in  $y$  ideally spaced by 0.38 cm ( $0.4\lambda$ ). A phase gradient was introduced to steer the main beam  $30^\circ$  from boresight. Position errors were then simulated by using (1) to calculate the probe response at nonideal measurement locations. In this setup, there are about 26,000 simulated measurements and about 20,000 unknowns.

Figure 2 shows the result for a case with a peak position error of  $1.1\lambda$  and an rms error of  $0.52\lambda$ . (These errors are extreme compared to the desired tolerances of  $\lambda/50$  to  $\lambda/100$ ).

The pattern computed ignoring probe position errors bears little resemblance to the correct pattern—the main beam is no longer recognizable. If we correct only for the  $z$  position errors, which are generally considered more significant than the transverse errors,

much of the true pattern is recovered. However, the gain is still about 1 dB low, and there are anomalous sidelobes. There is no discernible difference between the actual and the fully position corrected patterns.

### Conclusions

The algorithms discussed here are robust alternatives to complicated mechanical schemes designed to reduce probe position errors. In principle, computational uncertainties can be reduced to insignificance compared to other sources of uncertainty.

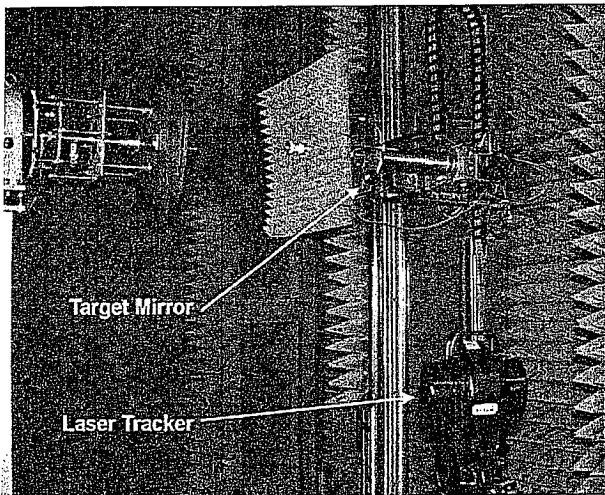


Figure 1. Laser tracker set up for recording probe position.

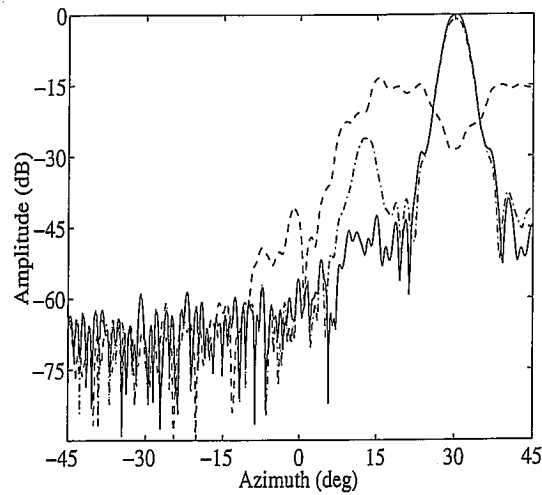


Figure 2. H-plane pattern of an antenna with a steered beam. The solid line corresponds to the corrected and to the actual pattern. The dashed line shows the result of ignoring the position errors. The dash-dotted line is the result of correcting for only the  $z$  position errors.

### References

- [1] R. C. Wittmann, B. K. Alpert, and M. H. Francis, "Near-field antenna measurements using nonideal measurement locations," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 43–48, May, 1998.
- [2] R. C. Wittmann, B. K. Alpert, and M. H. Francis, "Near-field, spherical scanning antenna measurements with nonideal probe locations," *IEEE Trans. Antennas Propagat.*, vol. 52, pp. 2184–2186, August 2004